Comparison of two approaches to internal jugular vein cannulation in young children: ultrasonographic evaluation

Dong Hun Kim, and Eun Ha Suk*

Background: Percutaneous cannulation of internal jugular vein is difficult in pediatric patients because of its small size and anatomic variation. The aim of this study is to investigate cross-sectional area and relative anatomy of right internal jugular vein with respect to the carotid artery in two approaches and thereby to find ideal cannulation site in young children.

Methods: The cross-sectional area of right internal jugular vein and the degree of the carotid artery overlap was evaluated in 47 children using ultrasound at two levels; 1) at the cricoid cartilage (high approach) and 2) at the junction of the two heads of the sternocleidomastoid muscle (low approach).

Results: The cross-sectional area was significantly larger by about 28.8% in the low approach than that of the high approach (P < 0.01). The internal jugular vein was partially overlapping the carotid artery in 48.9% and completely overlapping in 42.6% in the low approach and in 44.7% and 34.0% in the high approach respectively. The carotid artery overlap was significantly higher in the low approach when compared with the high approach (P < 0.02).

Conclusions: In terms of cross-sectional area, the low approach with larger size is optimal for internal jugular vein cannulation. Although the degree of the carotid artery overlap was higher at the low approach, the internal jugular vein was partially or completely covering the carotid artery in most patients in both approaches. When attempting to cannulate the internal jugular vein, clinicians should be aware of the large anatomic variations.

Key Words: Cannulation, Children, Internal jugular vein, Ultrasound.

INTRODUCTION

Central venous cannulation is often required in pediatric patients undergoing anesthetic management of major surgery for intensive care of hemodynamic monitoring, fluid management and vasoactive drug therapy. The right internal jugular vein (RIJV) is preferred for central venous access because of the shorter and more direct route to the superior vena cava, absence of the thoracic duct and the low level of cupula of the pleura. However, RIJV cannulation is more difficult in children than in adults probably due to the smaller size of the vein and its anatomic variations with respect to the carotid artery (CA) [1-3]. Ultrasound guided central vein cannulation has been shown to increase the success rate and reduce the incidence of traumatic complications in pediatric patients [4,5]. However, portable ultrasound devices are not always available.

There have been several studies to evaluate the cross-sectional area (CSA) or anatomic position of RIJV in pediatric patients [3,6-8], but none of these studies evaluated the CSA of RIJV and the relative position of RIJV with respect to the CA simultaneously and thus find ideal cannulation site.

During RIJV cannulation, venous blood return may not be achieved until the needle is withdrawn because the pressure of the advancing needle can cause the RIJV to collapse and lead to simultaneous puncture of anterior and posterior wall of vein (double wall puncture). Double wall puncture may cause incidental CA puncture when the artery is overlapped by the vein.

The incidence of double wall puncture during central venous cannulation was about 51% in pediatric patients which was
significantly higher than that of adult populations [9]. Therefore, increase overlap of CA by the RIJV would increase the risk of accidental arterial puncture which is the most common complication related to catheter insertion into the RIJV [10]. On the other hand, an increase in the size of the RIJV would help practitioners place venous catheterization more successfully [11]. Theoretically, the site with a larger CSA and less CA overlap would be the ideal site for RIJV cannulation.

This study was designed to evaluate the CSA and anatomic relationship of RIJV and CA in two approaches and to find ideal cannulation site for RIJV in anesthetized young children using ultrasound.

**MATERIALS AND METHODS**

After obtaining institutional ethics committee’s approval and written informed consent from patients’ parent, forty-seven young children, from 12 to 72 months of age, ASA physical status I or II, undergoing general anesthesia for elective operation were studied. Types of the operations were hydrocelectomy, orchiopexy, inguinal hernioplasty, pyeloplasty, sphincterectomy, colostomy repair, pyloromyotomy and hemangioma excision. Premature patients and patients with congenital diseases, malformations or history of central venous access were excluded from the study. After induction of general anesthesia by either intravenous or inhalational route, the trachea was intubated with atracurium. Mechanical ventilation was initiated (tidal volume of 10 ml/kg with no application of positive end expiratory pressure) and anesthesia was maintained using sevoflurane 2−3% in an oxygen/air mixture. Patient was positioned as if for cannulation of RIJV. Briefly, patient was supine on a horizontal table with the neck slightly extended on a rolled towel placed under the shoulders. Patient’s head was then rotated to the contralateral side such that the upper nasal bones were displaced about 30−35 degrees using a protractor. The CSA of the RIJV and anatomic relationship with the CA were assessed at two anatomical levels; 1) at the cricoid cartilage (high approach) and 2) at the junction of the two heads of the sternocleidomastoid (SCM) muscle (low approach), using a two-dimensional ultrasound (Sonos 4500®, Philips, MA, USA with a 5 MHz linear probe). The probe was applied perpendicularly to the skin with minimal pressure to prevent RIJV compression and deformation. The RIJV was identified based on its anatomical location, compressibility and the absence of pulsation. After freezing the image on the ultrasound screen, venous circumference was delineated by the electronic marker and CSA was calculated with the machine’s inbuilt ellipse function during examination. The positions of the RIJV in relation to the CA were determined as either no overlap (the RIJV is located completely lateral to CA on the ultrasound image), partial overlap (the RIJV overlapped the diameter of CA by up to 50%) or completely overlap (the RIJV overlapped the diameter of CA by more than 50%). All images were obtained at end-inspiration when the size of the RIJV was maximal and all data were obtained by another investigator who is blinded to the patients’ condition and sequence of the measurements.

Statistical analysis was carried out by a statistical software package (SPSS 12.0®, SPSS, Chicago, USA). Data were analyzed by using paired Student’s t-test and Wilcoxon’s signed rank test and P values of <0.05 were considered statistically significant. A mean difference of 25% or more in the CSA was considered clinically significant.

**RESULTS**

A total of 47 children completed the study and demographic data of the patients are presented in Table 1.

The mean RIJV CSA was 0.52 ± 0.17 cm² at the high approach and 0.69 ± 0.27 cm² in the low approach. The RIJV CSA was significantly larger in the low approach compared with the high approach by about 28.8 ± 12.3% (P < 0.01) (Fig. 1). Overall degree of the overlapping was significantly higher in the low approach (P < 0.02). However, the degree of the overlapping was significantly increased in the low approach when there was no overlap in the high approach (P < 0.04) whereas, there was no significant increase in the degree

<table>
<thead>
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<th>Table 1. Subjects Demographics</th>
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<tr>
<td>Age (months)</td>
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<tr>
<td>Weight (kg)</td>
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<tr>
<td>Gender (M/F)</td>
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<tr>
<td>Diagnosis (n)</td>
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<tr>
<td>Inguinal hernioplasty</td>
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<td>Hemangioma excision</td>
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Values are expressed as mean ± SD or number.
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Table 2. Relative Position of Right Internal Jugular Vein with Carotid Artery in the High and Low Approaches

<table>
<thead>
<tr>
<th>Anatomic position</th>
<th>No overlap</th>
<th>Partial overlap</th>
<th>Complete overlap</th>
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<tr>
<td>High approach</td>
<td>10 (21.3%)</td>
<td>21 (44.7%)</td>
<td>16 (34.0%)</td>
</tr>
<tr>
<td>Low approach*</td>
<td>4 (8.5%)</td>
<td>23 (48.9%)</td>
<td>20 (42.6%)</td>
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</table>

Numerical values in table indicate the number of patients in that particular group with that particular position. Values in parentheses are the percentage of patients in that group with that particular position. High approach: the level of the cricoid cartilage, Low approach: the level of the junction of two heads of the sternocleidomastoid muscle. *P < 0.05 compared with the high approach. \(^P < 0.05\) compared with the high approach in the same anatomical position.

The present study demonstrated that the CSA of the RIJV was significantly larger in the low approach than the high approach. A mean increase of 25% or more in CSA is generally considered to be clinically significant in terms of facilitating RIJV cannulation in children [12]. The CSA of the RIJV can be different with the site of measurement and the head position [7]. We evaluated the RIJV in two levels of the cricoid cartilage and the junction of two heads of SCM muscle because these are commonly used approaches for RIJV cannulation in pediatric patients. The lower site than the junction of two heads of SCM muscle is not recommended because of the possibility of serious complications, such as pneumothorax and intrapleural hemorrhage [13]. It is known that the RIJV CSA is larger in neutral head position compared with that in head rotated position [7,14]. Nevertheless, we positioned the head rotated about 30–35 degrees to the contralateral side because the approach to the puncture site is difficult in neutral position due to the large head and short neck of children.

Our study also demonstrated that the RIJV overlapped the respective CA partially or completely in most patients in both two approaches. Although the overall degree of CA overlapping is significantly higher in the low approach than the high approach, this increase is mainly due to the increased overlap when there was no overlap in the high approach.

In traditional landmark technique, pulsation of the CA may be the only anatomical landmark to identify the position of the RIJV. Therefore, there are technical difficulties probably because external landmarks do not correlate exactly to the location of the vessels. The variation in the anatomical relationship between

DISCUSSION

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Fig. 1. Ultrasound images of right internal jugular vein in a 14-month-old child showing the increase in cross-sectional area in the low approach (B) compared with the high approach (A). High approach: the level of the cricoid cartilage, Low approach: the level of the junction of the two heads of the sternocleidomastoid muscle. CA: carotid artery, RIJV: right internal jugular vein.
the RIJV and the CA may account for failure of cannulation or inadvertent arterial puncture. The incidence of CA puncture in children has been reported to be as high as 26.7% [4] and the incapacity of obtaining the cannulation of IJV through puncture is referred in 19.4% [5]. Accidental arterial puncture is usually benign, but can result in serious complications, such as, arterial catheterization, uncontrolled hemorrhage, hematoma and arteriovenous fistula [15,16].

It has been known that there is considerable variation in the position of the RIJV in relation to the CA. Roth et al. demonstrated that the IJV was partially covering the CA in 54.4% and completely overlapping the CA in 24.4% in preschool children with the head in a neutral position at the level of cricoid cartilage [6]. Mallinson et al. reported that the IJV is anterior or anterolateral to the CA in 36% of the children at the level of cricoid cartilage and 60% at the level between the two head of SCM muscle with the heads rotated 45 degrees to the left, and thus, they thought that the higher approach would be the safer route for cannulation [7]. Our findings are consistent with previous studies in that there were considerable anatomic variations between the RIJV.

During central venous cannulation, various factors such as size of the vein, presence of vascular anomalies, experience of the operator, position of the patients and history of previous cannulation can affect the success and complication rate in pediatric patients. It is likely that the difficulty associated with the RIJV catheterization can be mostly because of the small vein size in pediatric patients. Gordon et al. demonstrated that the rate of successful first pass catheterization of internal jugular vein is correlated directly with venous dimension [11]. Tercan et al. described that the incidence of double wall puncture during central venous cannulation is associated with the size of RIJV because the rate of double wall puncture was significantly higher in children younger than 5 years than in children older than 5 years [9]. The CA overlap is related with the accidental arterial puncture when the cannulation needle passes through the compressed vein into the overlapping CA. Therefore, the larger CSA of RIJV could lower the rate of double wall puncture in cannulation and thereby, prevent the inadvertent arterial puncture.

Under ultrasonographic guidance, it is somewhat possible to avoid CA puncture by targeting unoverlapping portion of RIJV, thus the low approach with larger CSA is ideal for cannulation. Even though when ultrasound is unavailable, we also think that the low approach with larger size would be optimal because the degree of overlapping does not increase significantly in the low approach in most children in whom there was any degree of overlapping in the high approach. However, we did not examine the real success rate of RIJV cannulation and associated complications in this study therefore, further studies are required to determine whether either approach is more successful and to access the frequencies of complications with both approaches.

In conclusion, considering the RIJV CSA, the low approach with larger size seems to be optimal for RIJV cannulation in young children. However, there is a large amounts of anatomic variation between the RIJV and CA in both two approaches, and thus, when attempting to cannulate the RIJV in young children, clinicians should be aware of the anatomic variation.

REFERENCES

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